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by

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MULTI-FOCAL LENGTH AND MULTI-CHANNEL HOLOGRAPHIC OPTICAL ELEMENT

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A new holographic optical element (HOE) consisting of the hololenses with different focal lengths and diffractional channels is described. The object space axes of all hololenses in the HOE are the same, while each optical axis in the image space is different. By the aid of such HOE, the object planes at different distances can be imaged into the corresponding channels. Therefore, a 3-D object field may be displayed by many 2-D images. The primary experimental results for sampling 3-D particles field are presented.

I: INTRODUCTION

Optical elements manufactured using optics hologram technology to can easily form a number of elements into the same area of hologram recording material. Material made up of this type of multiple-focal length hologram lens arrays is already widely used for pattern recognition in multiple matching wave filter systems[1]. Each lens in the multiple focal length arrays used in matching wave filters has the same focal length and image diffraction direction This article will introduce an element that is composed of different focal length and different diffraction channel holographic lenses. It is called the multiple focal length multi-channel holographic optical element.

II: BASIC STRUCTURE AND THE MANUFACTURE OF MULTI-FOCAL LENGTH MULTI-CHANNEL HOLOGRAPHIC OPTICAL ELEMENT

The image forming function of holographic lenses on recurrent

light waves is determined by the phase factors of the two beams of light waves which recorded it[2]. Using Champagne[3] symbol definition method, the hologram imaging formula is:

$$1/R_i=1/R_c \pm \mu(1/R_0-1/R_r), \tag{1}$$

$$\sin\alpha_i=\sin\alpha_c \pm \mu(\sin\alpha_0-\sin\alpha_r), \tag{2}$$

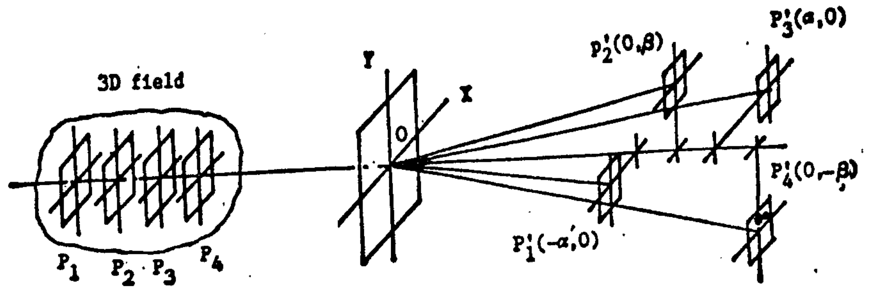
$$\cos\alpha_i\sin\beta_i=\cos\alpha_c\sin\beta_c \pm \mu(\cos\alpha_0\sin\beta_0-\cos\alpha_r\sin\beta_r), \tag{3}$$

In these equations, (R_i, α_i, β_i)、(R_c, α_c, β_c)、(R_0, α_0, β_0) (R_r, α_r, β_r) correspond respectively to the focal point, reappearance point, objective point and reference light point. the symbol "$\pm$" indicates plus or minus diffraction level. Because only positive images are required, the negative symbol is used. Also, when the wavelength is not changed, then μ=1. From equation (1) we can obtain the focal length of the holographic lens as

$$1/f=1/R_0-1/R_{r0} \tag{4}$$

When making multi-focal length multi-channel holographic optical elements, different R_o and R_r values are chosen first which give different focal lengths. At the same time, chose lenses with the same α_o and β_o angles, and let $\alpha_o=\beta_o=0$, while α_r and β_r are different. When the reappearing light angle of incidence angle $\alpha_o=\beta_o=0$, from equations (2) and (3) we obtain $\alpha_i=\alpha_{ro}$, $\beta_i=\beta_{ro}$. Therefore, when recording the holographic lenses, choosing the R_o and R_r, and the α_r and β_r will make it possible for the element to contain multiple focal lengths and multiple diffraction channels. Figure 1 presents the image plane arrangement and the imaging principles of a four lens multi-focal length multi-channel holographic optical element. In this figure, the four cross sections in the 3-D field are individually imaged by one of four lenses in four diffraction directions. In order to ensure each lens is the sam power, each image plane is distributed on a different cross section. Also, the diffraction light axis and incident light axis of each lens has the same included angle. This way it can cause each lens to have the same image quality.

Fig.1: Scheme of 3D Field Measurement



P_1, P_2, P_3, P_4—Sampled planes in 3D field, P_1', P_2', P_3', P_4'—Conjugate planes of P_1, P_2, P_3, P_4

When making each individual lens for a multi-focal length multi-channel holographic element, the authors used an intermediate hologram with phase factors for fairly good imaging and phase factors which satisfy the Bragg diffraction conditions, forming a holographic element which can generate an even image plane for limited distance objective images and for parallel light entering at a perpendicular. The manufacturing process is shown in Figure Two. We first used the process in 2(a) to make the H_1 element suitable for imaging objects at a limited distance. Its phase factor is

$$\Phi_H^1 = \phi_0^1 - \phi_R^1 \qquad (5)$$

Then, we placed H1 in (2)b, and using the H_1 reappearing light beam as the objective light of the intermediate hologram H_{int}, $\phi_0^{int} = \phi_i'$ and H_{int} phase factor is

$$\Phi_H^{int} = \phi_0^{int} - \phi_R^{int} = \phi_i^1 - \phi_R^{int} = \phi_C^1 - \Phi_H^1 - \phi_R^{int} \qquad (6)$$

Letting the H_1 reappearing light be the plane wave entering at a perpendicular angle, its phase on H_1 is $\phi_C' = 0$, then equation (6) becomes

$$\Phi_H^{int} = -\Phi_H^1 - \phi_R^{int} \qquad (7)$$

We made a number of intermediate holograms. They had different focal lengths and spacial diffraction directions. After making the intermediate holograms, we replaced them as shown in Figure 2(c). Where H1 had originally been, we recorded the final H_f needed. Using the ϕ_R^{int} conjugate light $\phi_C^{int} = -\phi_R^{int}$ to reproduce H_{int}

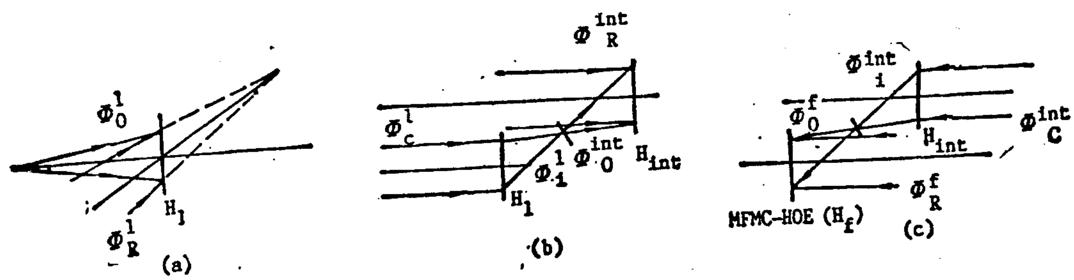
and using H_{int} image light wave ϕ_i^{int} as the H_1 object light $\phi_0^f=\phi_i^{int}=\phi_C^{int}-\Phi_H^{int}$. The H_{int} reference light used a plane wave at a perpendicular angle. Its phase was .Therefore, we finally obtained the final phase parameter of H_1, Φ_H^f:

$$\Phi_H^f=\phi_0^f=\phi_C^{int}-\Phi_H^{int}. \tag{8}$$

When $\phi_C^{int}=-\phi_R^{int}$ (9)

Substituting (7) in (8), $\Phi_H^f=\Phi_H^1$.

Fig. 2: Schematic for the Manufacture of MFMC-HOE by Recursive Design Technique.



Because the H_1 reference light is a perpendicularly entered plan wave, and because it also has the phase factors presented in equation (9), it can turn the parallel light projected object into a good quality image with even backlighting. This ensures the requirement that all the multiple lenses in the element image the objective fields on the same axis at the same time.

III: USING MULTI-FOCAL LENGTH MULTI-CHANNEL HOLOGRAPHIC OPTICAL ELEMENTS TO SAMPLE 3D PARTICLE FIELDS

The principles and optical circuits in the use of multi-focal length multi-channel holographic optical elements to sample 3D particle fields is shown in Figure 3. The holographic element shown in Figure 3 is composed of lenses L_A and L_B. The parallel planes A and A' and B and B' are the conjugated planes of L_A and L_B. Particles on plane A scatter the incoming light, and the scattered light is focussed on plane A' by lens L_A, thus obtaining

clear image of the particle on plane A'. Because the scattered light of this particle is a diffused spot on plane B, if is a diffused image on plane B'. By the same reasoning, particles on plane B only become distinct images on plane B'. In tests, the degree of clarity of particles on image planes can reflect the location of those particles in space. According to results by Thompson et al[4], the background depth range of particles under illumination such as light is $0.2d_2/\lambda$, where d is the diameter of the particle and λ is the wavelength. Therefore, if planes A and B are $\Delta L>0.2d_2\lambda$, then the clarity of the particles on planes A' and B' can be clearly divided.

Fig. 3: Imaging Principles of MFMC-HOE with two Holographic Lenses

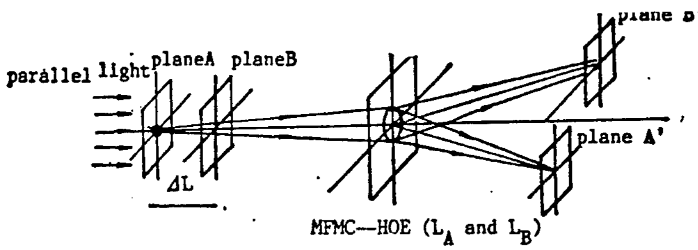
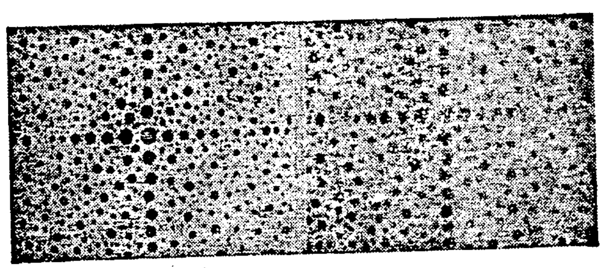


Fig. 4. Images of the Particles at Plane A

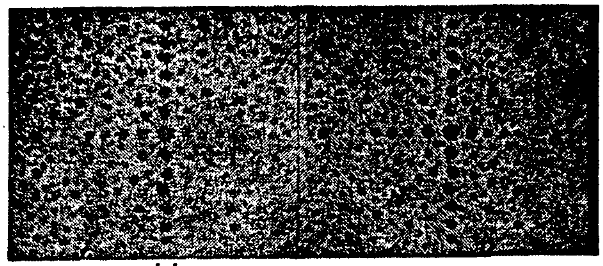


(a). Image at A'. (b). Image at B'.

In our experiments, we used particle plate shift along a light axis to replace different cross sections of particle fields to test the effectiveness of sampling by multi-focal length multi-channel holographic elements. The results of the test are shown in Figures

4 and 5. The holographic elements we used were composed of dichromic acid film. L_A had a focal length of 90 mm and L_b had a focal length of 120 mm.

Fig. 5. Images of Particles Taken at Plant B'



(a) (b)

(a). Images at A'. (b). Images at B'.

IV: CONCLUSIONS

By using the holographic method, it is possible to superimpose holographic lenses with different focal lengths and different diffraction directions to make multi-focal length multi-channel holographic optical elements. These elements can image objects in space and different objective distances along the light axis on corresponding image planes, thus displaying a single 3D objective field into a number of two dimensional fields. This type of element can also be used in the reverse, that is, forming a three dimensional field from two dimensional fields on a number of individual image planes.

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